PASIG PERFORMING ARTS
SPECIAL INTEREST GROUP

ORTHOPAEDIC SECTION
AMERICAN PHYSICAL THERAPY ASSOCIATION

APTA
American Physical Therapy Association
The Science of Healing. The Art of Caring.

PASIG MONTHLY CITATION BLAST: No.50 **May 2010**

Dear PASIG members:

Our next Combined Sections Meeting will be held in New Orleans, February 9 –12, 2011. CSM abstract submission is open and the June 2nd deadline is quickly approaching. I hope many of you are planning to submit an abstract related to performing arts. Abstract topics can include pilot and full scientific research studies, case studies, clinical topics, or special interest reports. Go to http://www.apta.org/csm for more information and to connect to Scholar One Abstract Central for electronic submission. If PASIG members would like feedback on an abstract prior to submission, please contact me and either I or someone on the PASIG Research Committee will help you or recommend someone knowledgeable in your area.

Don't forget, the PASIG sponsors an annual student research scholarship. This award is to recognize students, who have had an abstract accepted to CSM, for their contribution to performing arts medicine and research. We encourage you to mentor your students in PA-related research and have them apply! If the PASIG Research Committee can assist students, please contact us. For more information on the research award please check our webpage (http://www.orthopt.org/sig_pa.php). Students with additional questions can contact Amy Humphrey (ahumphrey@bodydynamicsinc.com).

Performing Arts continuing education, courses, and related conferences:

Orthopaedic Section Independent Study Course. *Dance Medicine: Strategies for the Prevention and Care of Injuries to Dancers*. This is a 6-monograph course and includes many PASIG members as authors. This home study course can be purchased at http://www.orthopt.org/independent2.php. PASIG members are currently developing a new Performing Arts Independent Study Course, so be on the lookout for its release.

Principles of Dance Medicine: Clinical Management of the Dancer Patient
July 15 – 18, 2010
New York, NY
Email: harkness@nyumc.org Web: www.danceinjury.org

Performing Arts Medicine Association (PAMA)
28th Annual Symposium on Medical Problems of Musicians and Dancers
July 29 – Aug 1, 2010

Snowmass, CO
Contact: http://www.artsmed.org/

NEW PASIG monograph available in September 2010.

International Association for Dance Medicine and Science (IADMS) 20th Annual Meeting
October 28 – 31, 2010
October 31: Biomechanics and Dance Workshop
Birmingham, UK
Contact: http://www.iadms.org

If you know of other courses of interest to our membership, please send the information to: Amy Humphrey PT, DPT, OCS, MTC; ahumphrey@Bodydynamicsinc.com

Thank you to those members who have updated their membership profile. You can now be found easier by your colleagues and we have received good feedback from you. **For those members who have not yet updated your membership profile, it only takes a few minutes, so please use the link below** (must log in): https://www.orthopt.org/surveys/membership_directory.php"

For this May Citation BLAST, I've selected the topic *Bone Health in Gymnasts.* The general format is an annotated bibliography of articles from 2000 – 2010. The PASIG Research Committee initiated this monthly Citation BLAST on performing arts-related topics in June 2005 in the hopes of encouraging our members to stay current in the literature and, perhaps, consider conducting research themselves. Each month we send a new list of performing arts (PA) citations to members of the PASIG to further the pursuit of PA-related scholarship. The BLASTS and updated libraries are posted on the PASIG webpage for our members to access and download. (Information about EndNote referencing software can be found at http://www.endnote.com, including a 30-day free trial).

Upcoming citation topics will include Pilates, Taping, Yoga, nutrition, and eating disorders. Anyone interested in contributing to one of these topics or to suggest a new special topic, please contact me.

As always, your comments, suggestions, and entry contributions to these Citation BLASTs are welcome. Please drop me an e-mail anytime.

Regards,
Shaw

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Bone Health in Gymnasts

In treating female performing artists and athletes, we are on the lookout for signs of the female athlete triad: disordered eating, amenorrhea or oligomenorrhea, and osteopenia or osteoporosis. In gymnasts, stress fractures may occur in more unusual locations such as the talar body, medial malleolus, olecranon, scaphoid, and clavical as well as the more common tibia, metatarsals, and spine.

However, what is the overall status of their bone health? Despite disordered eating, amenorrhea, and delays in pubertal development, there are indications that the mechanical loading of both the lower and upper extremities in gymnastics stimulates beneficial bone and skeletal muscle hypertropy. This increase in bone mineral density seems to be maintained in former gymnasts compared to controls.

While this is good news, one study suggests the importance of monitoring Vitamin D and calcium status in the adolescent gymnast to ensure the body's access to the materials necessay for optimal bone health.

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Bareither ML, Grabiner MD, et al. (2008). Habitual site-specific upper extremity loading is associated with increased bone mineral of the ultradistal radius in young women. J Womens Health **17**(10): 1577-1581.

INTRODUCTION: Osteoporosis and osteopenia are major contributors to the high incidence of fractures in older women. Habitual loading plays a crucial role in the acquisition and maintenance of bone. It may be possible to develop clinical interventions based on targeted modes of physical loading that can improve bone health and reduce fractures in women. If so, an important first step is determining the degree to which common fracture sites, such as the distal radius are responsive to habitual loading. METHODS: The bone mineral density (BMD) and bone mineral content (BMC) of the ultradistal radius of 15 female gymnasts were compared with those of an age-matched, mass-matched, and height-matched control group. The hypothesis that the ultradistal radius BMD and BMC in gymnasts would be higher than those of the control group was tested using a 2 x 2 (left/right x group) repeated measures analysis of variance (MANOVA). RESULTS: After adjusting for the between-group difference in the influence of body mass, the gymnasts had 24% larger BMD and a 34% larger BMC at the ultradistal radii than the control group ($p < 0.001$). CONCLUSIONS: These results suggest that the ultradistal radius is responsive to the types and magnitudes of load encountered during gymnastics. A responsive distal radius is a necessary prerequisite to the development of loading-based interventions to increase ultradistal radius bone quality. Such interventions have the potential to significantly increase distal radius strength, thereby reducing the incidence of fracture.

Courteix D, Rieth N, et al. (2007). Preserved bone health in adolescent elite rhythmic gymnasts despite hypoleptinemia. Horm Res **68**(1): 20-27.

BACKGROUND/AIMS: Leptin is linked to hormonal disturbances occurring in anorexia and positively linked with bone mineral density. The aim of this study was to determine whether hypoleptinemia occurring in rhythmic gymnasts may affect bone health. METHOD: Leptin, insulin, cortisol, IGF1 levels and bone markers were determined in 36 rhythmic gymnasts (EG) and 20 controls (C). Body composition, BMD at the whole body (WBBMD), lumbar spine (LSBMD) and bone ultrasound properties (SOS, BUA) were measured. RESULTS: The rhythmic gymnasts had lower fat mass and leptin level than the controls. There was no

difference for IGF1, cortisol and insulin levels. Bone turnover rate was higher in elite gymnasts. The uncoupling index showed that remodeling favored the bone formation. LSBMD, WBBMD, SOS and BUA were higher in elite gymnasts after adjustment for fat mass. Leptin correlated positively with fat mass and negatively with physical activity. CONCLUSION: High impact training is able to counterbalance bone effects usually encountered in hormonally disturbed subjects. Our results suggest that hypoleptinaemia might be related to direct osteogenic effects and indirect hormonal mechanisms including preservation of IGF and cortisol levels.

Dowthwaite JN, Flowers PP, et al. (2007). Bone geometry, density, and strength indices of the distal radius reflect loading via childhood gymnastic activity. J Clin Densitom **10**(1): 65-75.

The distal radius bears unique forces during gymnastic activity. Its relatively simple anatomy, minimal soft tissue envelope, and varied composition make the distal radius ideal for evaluating the effects of loading on bone properties. For 56 premenarcheal gymnasts and nongymnasts, ultradistal and 1/3 distal radius DXA scans measured bone mineral content (BMC), areal bone mineral density, and projected area. Simplified geometric models were used to generate bone mineral apparent density (BMAD), geometric indices, strength indices, and fall strength ratios. Ratios of regional BMC vs total body fat-free mass (FFM) were calculated. Separate Tanner I and II analyses of covariance adjusted bone parameters for age and height. Ratios were compared using maturity-matched analyses of variance. At the 1/3 region, periosteal width, BMC, cortical cross-sectional area, and section modulus were greater in gymnasts than nongymnasts ($p<0.05$); 1/3 BMAD means were equivalent. Ultradistal BMAD, BMC, and index for structural strength in axial compression were higher in gymnasts than nongymnasts; ultradistal periosteal width was only larger in Tanner I gymnasts. Fall strength ratios and BMC/FFM ratios were greater in gymnasts ($p<0.05$). Geometric and volumetric responses to mechanical loading are site specific during late childhood and early adolescence.

Dowthwaite JN, Kanaley JA, et al. (2009). Muscle indices do not fully account for enhanced upper extremity bone mass and strength in gymnasts. J Musculoskelet Neuronal Interact **9**(1): 2-14.

OBJECTIVES: Muscular forces are an important determinant of bone strength, but bone may also adapt to non-muscular loading. We tested the hypothesis that loads associated with childhood gymnastics yield high arm bone mass (BMC), bone size and bone strength, independent of arm lean mass (FFM) and muscle cross-sectional area (CSA). METHODS: Total body DXA and distal radius pQCT scans were performed on 33 post-menarcheal girls (19 ex/gymnasts, 14 non-gymnasts). Physical activity and calcium intake were assessed by questionnaire. For the non-dominant arm, pQCT measured bone strength indices and bone CSA (total, cortical) (4%, 33% sites); DXA measured arm FFM, arm BMC and skull BMC. Multiple regression analyses assessed gymnastic exposure, arm FFM, gynecological age and stature as predictors of bone parameters. RESULTS: Bone outcomes at loaded upper extremity sites were 10-42% greater in ex/gymnasts than non-gymnasts. Gymnastic exposure remained a consistent, significant predictor of upper extremity skeletal parameters after accounting for the effects of muscle parameters, gynecological age and height. CONCLUSIONS: Considering the effects of either arm FFM or muscle CSA, indices of bone mass, geometry and theoretical strength are disproportionately elevated after gymnastic exposure. Thus, non-muscular loading may be a distinct and important determinant of human skeletal structure.

Dowthwaite JN, Scerpella TA (2009). Skeletal geometry and indices of bone strength in artistic gymnasts. J Musculoskelet Neuronal Interact **9**(4): 198-214.

This review addresses bone geometry and indices of skeletal strength associated with exposure to gymnastic loading during growth. A brief background characterizes artistic

gymnastics as a mechanical loading model and outlines densitometric techniques, skeletal outcomes and challenges in assessment of skeletal adaptation. The literature on bone geometric adaptation to gymnastic loading is sparse and consists of results for disparate skeletal sites, maturity phases, gender compositions and assessment methods, complicating synthesis of an overriding view. Furthermore, most studies assess only females, with little information on males and adults. Nonetheless, gymnastic loading during growth appears to yield significant enlargement of total and cortical bone geometry (+10 to 30%) and elevation of trabecular density (+20%) in the forearm, yielding elevated indices of skeletal strength (+20 to +50%). Other sites exhibit more moderate geometric and densitometric adaptations (5 to 15%). Mode of adaptation appears to be site-specific; some sites demonstrate marked periosteal and endosteal expansion, whereas other sites exhibit negligible or moderate periosteal expansion coupled with endocortical contraction. Further research is necessary to address sex-, maturity- and bone tissue-specific adaptation, as well as maintenance of benefits beyond loading cessation.

Eser P, Hill B, et al. (2009). Skeletal benefits after long-term retirement in former elite female gymnasts. J Bone Miner Res **24**(12): 1981-1988.

Bone strength benefits after long-term retirement from elite gymnastics in terms of bone geometry and volumetric BMD were studied by comparing retired female gymnasts to moderately active age-matched women. In a cross-sectional study, 30 retired female gymnasts were compared with 30 age-matched moderately active controls. Bone geometric and densitometric parameters were measured by pQCT at the distal epiphyses and shafts of the tibia, femur, radius, and humerus. Muscle cross-sectional areas were assessed from the shaft scans. Independent t-tests were conducted on bone and muscle variables to detect differences between the two groups. The gymnasts had retired for a mean of 6.1 +/- 0.4 yr and were engaged in <or=2 h of exercise per week since retirement. At the radial and humeral shafts, cortical cross-sectional area (CSA), total CSA, BMC, and strength strain index (SSIpol) were significantly greater (13-38%, p <or= 0.01) in the retired gymnasts; likewise, BMC and total CSA were significantly greater at the distal radius (22-25%, p <or= 0.0001). In the lower limbs, total CSA and BMC at the femur and tibia shaft were greater by 8-11%, and trabecular BMD and BMC were only greater at the tibia (7-8%). Muscle CSA at the forearm and upper arm was greater by 15-17.6% (p <or= 0.001) but was not different at the upper and lower leg. Past gymnastics training is associated with greater bone mass and bone size in women 6 yr after retirement. Skeletal benefits were site specific, with greater geometric adaptations (greater bone size) in the upper compared with the lower limbs.

Falk B, Bronshtein Z, et al. (2003). Quantitative ultrasound of the tibia and radius in prepubertal and early-pubertal female athletes. Arch Pediatr Adolesc Med **157**(2): 139-143.

BACKGROUND: Physical exercise during childhood has been shown to enhance bone mineral density, thus reducing the risk of osteoporosis. OBJECTIVE: To examine bone properties, as measured by quantitative ultrasound, in prepubertal and early-pubertal female athletes engaged in impact and nonimpact sports. DESIGN: Survey. SETTING: General community. PARTICIPANTS: Twenty-five acrobatic gymnasts, 21 swimmers, and 21 control subjects. Athletes had been training for at least 1(1/2) years. MAIN OUTCOME MEASURE: Bone speed of sound (bilateral) at the distal radius and the midtibia. RESULTS: Gymnasts were significantly shorter and lighter than swimmers and control girls (P<.001) but had a body mass index similar to that of swimmers. Adiposity was lower in athletes than in controls. Speed of sound did not correlate with measures of body size. Higher mean +/- SD radial speed of sound values (nondominant side) were observed in gymnasts (3764 +/- 104 m/s; P =.045) than in swimmers and control girls (3732 +/- 99 and 3721 +/- 83 m/s, respectively). Mean +/- SD tibial speed of sound values (nondominant side) were similar in gymnasts and swimmers (3629 +/- 87 and 3619 +/- 78 m/s, respectively) and higher in the athletic groups than in the control group (3516 +/- 127 m/s; P<.001). In all 3 groups, no

differences were observed between dominant and nondominant sides in the radii or tibias. CONCLUSIONS: Physical exercise, impact and nonimpact, is related to enhanced bone properties, as measured by quantitative ultrasound. Longitudinal studies using various modes of bone evaluation are necessary to determine the long-term effect of various types of exercise on bone properties.

Fallon KE, Fricker PA (2001). Stress fracture of the clavicle in a young female gymnast. Br J Sports Med **35**(6): 448-449.

Stress fractures of the clavicle are rare. This is the report of one such fracture in a 10 year old female gymnast, who presented with a six week history of medial clavicular pain. Radiographs and a computed tomography scan showed an undisplaced fracture through the medial third of the clavicle extending inferiorly to the rhomboid fossa in the inferior aspect of the clavicle. Pathological fracture was excluded by magnetic resonance imaging. The patient was treated conservatively and was able to return to full training eight weeks later.

Faulkner RA, Forwood MR, et al. (2003). Strength indices of the proximal femur and shaft in prepubertal female gymnasts. Med Sci Sports Exerc **35**(3): 513-518.

INTRODUCTION/PURPOSE: The role of impact loading activity on bone mass is well established; however, there are little data on the effects of exercise on bone geometry and indices of bone strength. The primary purpose of this study was to compare indices of bone strength at the proximal femur (PF) between elite premenarcheal gymnasts (N= 30) and age-matched controls (N= 30). METHODS: Structural properties of the proximal femur were derived from the hip analyses program and included measurement of subperiosteal width, endosteal diameter, cross-sectional area, bone mineral density, cross-section moment of inertia (CSMI), and section modulus (Z). These parameters were measured for two regions of the PF: the narrow neck (NN), and the shaft (S). In addition, a strength index (S-SI) was calculated at the shaft by dividing the Z at the shaft by the femur length. A secondary purpose was to compare bone mineral content (BMC) values at the total body, lumbar spine, and three sites at the PF (neck, trochanter, and total) between the groups. All dependent values were compared adjusting for height and weight using an ANCOVA procedure and for relative lean body mass.RESULTS The gymnasts had significantly greater size-adjusted strength indices (CSMI, Z, and SI) at the NN and S. Gymnasts also had significantly greater size-adjusted BMC at all sites investigated. However, these differences disappeared when adjusted for relative lean body mass. CONCLUSION: When adjusted for body size, gymnasts had significantly greater indices of both axial strength and bending strength at the NN region of the PF and S, as well as a greater bone SI at the femoral shaft. These differences may be related to greater relative lean body mass attained in gymnastics training.

Georgopoulos NA, Theodoropoulou A, et al. (2004). Growth and skeletal maturation in male and female artistic gymnasts. J Clin Endocrinol Metab **89**(9): 4377-4382.

We studied 262 athletes who were 13-23 yr old. There were 93 male and 169 female artistic gymnasts (AG). This study is unique in character, because all variables were measured on the field of competition (24th European Championship). Male AG had a higher height SD score than female ($P < 0.001$), with a higher reported target height SD score ($P < 0.001$), a higher predicted final height ($P = 0.007$), a lower Delta height - target height ($P < 0.001$), a less delayed bone age ($P < 0.001$), a greater body mass index (BMI) ($P < 0.001$), a lower mean body fat ($P<0.001$), and an older age of onset of training ($P < 0.001$). In a subgroup of athletes who had reached final height, male AG had a higher weight SD score than female ($t = 4.322$, $P < 0.001$), with a higher reported target height SD score ($t = 18.9$, $P<0.001$), but a greater Delta final height-target height ($t= 6.641$, $P < 0.001$). Height SD score was positively correlated to reported target height SD score ($P = 0.009$ and $P = 0.006$, respectively) and to weight SD ($P < 1$ and $P < 0.001$, respectively) for both male and female AG, as well as to

BMI for female AG (P<0.001), and negatively to Delta age - bone age (P < 0.001 and P = 0.003, respectively) and to predicted height SD score (P = 0.001 and P < 0.001, respectively). Using multiple regression analysis, height SD score was positively correlated to predicted height SD score for both male (P < 0.001) and female (P = 0.005) AG, as well as to weight SD score (P < 0.001) for female AG and negatively to BMI (P < 0.001) for female AG and to Delta age - bone age (P < 0.001) for male AG. In conclusion, a deterioration of growth in AG was observed. For both sexes, genetic predisposition to final height, although altered, was not disrupted.

Helge EW, Kanstrup IL (2002). Bone density in female elite gymnasts: impact of muscle strength and sex hormones. Med Sci Sports Exerc **34**(1): 174-180.

PURPOSE: The aim of this study was to investigate BMD in Danish female elite gymnasts and the relationships to maximal muscle strength, sex hormone concentrations, and menstrual status. METHODS: Six artistic gymnasts, five rhythmic gymnasts, and six controls aged 15-20 yr served as subjects. BMD (g x cm(-2)) of lumbar spine, proximal femur, distal radius, and whole body were measured by dual-energy x-ray absorptiometry (DXA) scanning. Maximal muscle strength (Nm) was measured in isokinetic trunk extension, trunk flexion, and knee extension. Serum concentrations of estrogen and progesterone in follicular and luteal phases were evaluated. RESULTS: Three out of six artistic gymnasts had amenorrhea, and two artistic and one rhythmic gymnast experienced oligomenorrhea. BMD in artistic gymnasts was greater than controls (24-45%, P < 0.05) in all sites except whole body. BMD in rhythmic gymnasts was greater than controls (4-26%, P < 0.05) in all sites except distal radius. In gymnasts, BMD correlated to both maximal muscle strength (0.60 < r < 0.85, P < 0.05) and serum progesterone (0.65 < r < 0.75, P < 0.05). CONCLUSION: In spite of oligomenorrhea or amenorrhea, it is possible for female gymnasts to maintain a high BMD in both the axial (L2-L4) and appendicular skeleton. The correlations between BMD and maximal muscle strength and progesterone concentration in gymnasts may indicate that within the same athletic group, progesterone concentration has a permissive role in bone formation, thus affecting the positive impact of muscle strength.

Jensen JE (1998). Stress fracture in the world class athlete: a case study. Med Sci Sports Exerc **30**(6): 783-787.

Stress fracture presents a difficult problem in the high performance, world-class athlete. Competitive demands provide little tolerance for, or agreement with, prolonged periods of rest which are the first line of conservative treatment methods. The use of a specifically programmed, pulsed, low-intensity ultrasound device to shorten the time of healing was investigated in a well-known gymnast with an Olympic deadline. Prior animal, in vitro, and clinical studies had established the safety and effectiveness of this device in fractures. The location of the stress injury was in the mid-tibia which is considered to present the greatest challenge to an early healing result. The low-intensity ultrasound device was prescribed for daily use at home. At 3 wk after the start of low-intensity ultrasound, the stress fracture responded well and the patient was allowed use of tumble track, trampoline, and to do some weight-bearing activities, such as jumping in the pool and loading-type activities. At 4.5 wk, the patient progressed to full workout activities and participated in a trial meet for the Olympics. At 6 wk, the patient's participation in the women's gymnastic team event was a factor in the United States receiving a gold medal.

Lovell G (2008). Vitamin D status of females in an elite gymnastics program. Clin J Sport Med **18**(2): 159-161.

OBJECTIVE: Vitamin D plays an important role in calcium and bone metabolism. In Australia it has been assumed that all young athletes have good vitamin D levels. A survey of females in an elite gymnastics program was undertaken to determine their vitamin D and dietary calcium status. DESIGN: Cross-sectional survey. SETTING: Females in an elite

gymnastics program at the Australian Institute of Sport. PARTICIPANTS AND OUTCOME MEASURES: Eighteen female gymnasts aged 10-17 years were assessed for vitamin D status (serum 25[OH]D) and dietary calcium intake. RESULTS: Fifteen were found to have levels below current recommended guidelines for optimal bone health (<75 nmol/L). Six had vitamin D levels below 50 nmol/L. Thirteen of the gymnasts also had daily dietary calcium intakes below the daily recommended intake for their age. CONCLUSIONS: Gymnasts and possibly other indoor athletes should be carefully reviewed for vitamin D and calcium status.

Matzkin E, Singer DI (2000). Scaphoid stress fracture in a 13-year-old gymnast: a case report. J Hand Surg Am **25**(4): 710-713.

We present a 13-year-old gymnast with a stress fracture of the scaphoid. Treatment was successful with immobilization for 8 weeks in a long arm spica cast followed by 4 weeks in a short arm splint.

Modlesky CM, Majumdar S, et al. (2008). Trabecular bone microarchitecture in female collegiate gymnasts. Osteoporos Int **19**(7): 1011-1018.

SUMMARY: Using high-resolution magnetic resonance imaging, we observed more developed trabecular bone microarchitecture in the proximal tibia of female collegiate gymnasts vs. matched controls. This suggests that high-load physical activity may have a positive effect on the trabecular microarchitecture in weight-bearing bone. INTRODUCTION: Participation in physical activities that overload the skeleton, such as artistic gymnastics, is associated with increased areal bone mineral density (aBMD); however, the status of trabecular microarchitecture in the weight-bearing bone of gymnasts is unknown. METHODS: Eight female collegiate artistic gymnasts and eight controls matched for age, height, body mass, gender and race were recruited for the study. Apparent trabecular bone volume to total volume (appBV/TV), trabecular number (appTb.N), thickness (appTb.Th) and trabecular separation (appTb.Sp) were determined using high resolution magnetic resonance imaging. Areal bone mineral density, bone mineral content (BMC) and bone area in the proximal tibia were determined using dual-energy X-ray absorptiometry. Group differences were determined using t-tests. The magnitude of group differences was expressed using Cohen's d (d). RESULTS: Gymnasts had higher appBV/TV (13.6%, d = 1.22) and appTb.N (8.4%, d = 1.45), and lower appTb.Sp (13.7%, d = 1.33) than controls ($p < 0.05$). Gymnasts had higher aBMD and BMC in the proximal tibia, although the differences were smaller in magnitude (d = 0.75 and 0.74, respectively) and not statistically significant ($p > 0.05$). CONCLUSION: The findings suggest that high-load physical activity, such as performed during gymnastics training, may enhance the trabecular microarchitecture of weight-bearing bone.

Omey ML, Micheli LJ, et al. (2000). Idiopathic scoliosis and spondylolysis in the female athlete. Tips for treatment. Clin Orthop Relat Res(372): 74-84.

Idiopathic scoliosis and spondylolysis can be common back problems in female athletes. Diagnosis and treatment can be difficult. With the notable trend toward increasing participation of women and girls in organized sports, it is necessary to know which sports carry additional risks for participants to have these two conditions develop and to determine treatment modalities. In general, idiopathic scoliosis is more prevalent in females and even may be higher in the athletes. Treatment options may include observation, the use of a brace, and surgery. In determining treatment, the type of sport and caliber of athlete must be considered in conjunction with the severity of the curve. Spondylolysis or a stress fracture of the posterior vertebral elements can be a common cause of back pain in an athlete. In many sports that are dominated by females (gymnastics, dancing, figure skating), the athletes carry a high risk of having spondylolysis or a stress fracture. Knowing the risk factors permits precise diagnosis and appropriate treatment. Treatment options include the use of a brace and surgery. In the current study, an extensive review of the literature in conjunction

with the extensive experience of a well-established sports medicine clinic at the authors' institution is presented.

Parr TJ, Burns TC (2003). Overuse injuries of the olecranon in adolescents. Orthopedics **26**(11): 1143-1146.

Overuse injuries are common in elite adolescent athletes due to intensive training demands. Overuse injuries of the olecranon have been divided into true stress fractures and osteochondroses. This article presents a third overuse injury, painful intraosseous edema, in elite adolescent athletes.

Pollock NK, Laing EM, et al. (2006). Former college artistic gymnasts maintain higher BMD: a nine-year follow-up. Osteoporos Int.

INTRODUCTION: If higher bone gains acquired from weight-bearing sports during growth persist into old age, the residual benefits could delay or even prevent osteoporotic fractures. The purpose of this study was to determine if the higher areal bone mineral density (aBMD) observed 15 years after competitive training and competition in former female college artistic gymnasts (GYM) compared with controls (CON) is maintained nine years later in this same cohort approaching menopause. In this 9-year follow-up, aBMD changes were also compared between GYM (n=16; aged 45.3+/-3.3 years) and CON (n=13; aged 45.4+/-3.8 years). METHODS: Total body, lumbar spine, proximal femur, femoral neck, leg, and arm aBMD were assessed at baseline and follow-up using dual-energy X-ray absorptiometry (DXA), (Hologic QDR-1000W). GYM had higher aBMD at all sites at follow-up ($P<0.05$; eta (2)>0.14). RESULTS: While there were no significant differences between groups for percent changes in aBMD at the total body, lumbar spine, total proximal femur, femoral neck, and arm, the change in leg aBMD was significantly different between GYM and CON ($P=0.05$; eta (2)=0.14). CONCLUSIONS: Former female college artistic gymnasts maintained significantly higher aBMD than controls 24 years after retirement from gymnastics training and competition. This study provides greater insight into the effects of past athletic participation on skeletal health in women approaching menopause.

Rossi F, Dragoni S (2005). Talar body fatigue stress fractures: three cases observed in elite female gymnasts. Skeletal Radiol **34**(7): 389-394.

OBJECTIVE: To introduce and emphasize the clinical and radiological findings of three talar body fatigue stress fractures in competitive athletes. DESIGN AND PATIENTS: Clinical and radiographic skeletal records of 24,562 athletes taken between 1962 and 2002 were retrospectively reviewed. Among these, 6851 files related to acute foot and ankle injuries or chronic post-traumatic sequelae were found. RESULTS: There were 925 (3.76%) stress fatigue fractures selected from the whole collection. Among these there were three cases (0.32%) of talar body stress fractures diagnosed in elite female gymnasts 15-17 years old. The negative first radiograph become positive 4-6 weeks later. Scintigraphy was positive at an early stage and consistent for the diagnosis. CT and MRI gave positive results 1-2 weeks after the beginning of symptoms which were always greatly diagnostic. CONCLUSIONS: The sports medicine literature lacks reports of talar body fatigue stress fractures. The poor initial sensitivity of radiography makes it problematic to establish an early diagnosis. A wise combination of scintigraphy, CT and MRI has therefore to be relied upon. Familiarity with this rare location for a stress fracture may prevent delayed diagnosis and long-lasting damage, both of which are important factors in competitive athletes.

Shabat S, Sampson KB, et al. (2002). Stress fractures of the medial malleolus--review of the literature and report of a 15-year-old elite gymnast. Foot Ankle Int **23**(7): 647-650.

Stress fracture of the medial malleolus is rare and not reported in children. We report a case of a 15-year-old elite gymnast with open physes sustaining a medial malleolar stress fracture. The patient was treated initially by rest and gradually returned to sport with full

recovery. Two months later she developed a complete fracture of the medial malleolus of the same side. This was treated surgically by open reduction and internal fixation with a cancellous screw and soon after the operation she returned to full activities. Emphasis is given to the suspected mechanism which led to this unique fracture and to the hormonal aspects in the professional adolescent gymnast. We recommend surgical treatment of stress fracture of the medial malleolus especially for elite athletes, leading to early recovery and return to sports activities.

Vicente-Rodriguez G (2006). How does exercise affect bone development during growth? Sports Med **36**(7): 561-569.

It is increasingly accepted that osteoporosis is a paediatric issue. The prepubertal human skeleton is quite sensitive to the mechanical stimulation elicited by physical activity. To achieve the benefits for bone deriving from physical activity, it is not necessary to perform high volumes of exercise, since a notable osteogenic effect may be achieved with just 3 hours of participation in sports. Physical activity or participation in sport should start at prepubertal ages and should be maintained through the pubertal development to obtain the maximal peak bone mass potentially achievable. Starting physical activity prior to the pubertal growth spurt stimulates both bone and skeletal muscle hypertrophy to a greater degree than observed with normal growth in non-physically active children. High strain-eliciting sport like gymnastics, or participation in sports or weight-bearing physical activities like football or handball, are strongly recommended to increase the peak bone mass. Moreover, the increase in lean mass is the most important predictor for bone mineral mass accrual during prepubertal growth throughout the population. Since skeletal muscle is the primary component of lean mass, participation in sport could have not only a direct osteogenic effect, but also an indirect effect by increasing muscle mass and hence the tensions generated on bones during prepubertal years.

Vicente-Rodriguez G, Dorado C, et al. (2007). Artistic versus rhythmic gymnastics: effects on bone and muscle mass in young girls. Int J Sports Med **28**(5): 386-393.

We compared 35 prepubertal girls, 9 artistic gymnasts and 13 rhythmic gymnasts with 13 nonphysically active controls to study the effect of gymnastics on bone and muscle mass. Lean mass, bone mineral content and areal density were measured by dual energy X-ray absorptiometry, and physical fitness was also assessed. The artistic gymnasts showed a delay in pubertal development compared to the other groups ($p<0.05$). The artistic gymnasts had a 16 and 17 % higher aerobic power and anaerobic capacity, while the rhythmic group had a 14 % higher anaerobic capacity than the controls, respectively (all $p<0.05$). The artistic gymnasts had higher lean mass ($p<0.05$) in the whole body and the extremities than both the rhythmic gymnasts and the controls. Body fat mass was 87.5 and 61.5 % higher in the controls than in the artistic and the rhythmic gymnasts ($p<0.05$). The upper extremity BMD was higher ($p<0.05$) in the artistic group compared to the other groups. Lean mass strongly correlated with bone mineral content ($r=0.84$, $p<0.001$), and multiple regression analysis showed that total lean mass explained 64 % of the variability in whole body bone mineral content, but only 20 % in whole body bone mineral density. Therefore, recreational artistic gymnastic participation is associated with delayed pubertal development, enhanced physical fitness, muscle mass, and bone density in prepubertal girls, eliciting a higher osteogenic stimulus than rhythmic gymnastic.

Vrable A, Sherman AL (2009). Elite male adolescent gymnast who achieved union of a persistent bilateral pars defect. Am J Phys Med Rehabil **88**(2): 156-160.

An adolescent 15-yr-old male competitive gymnast presented to a university-based multidisciplinary spine institute with a persistent low-back pain for 18 mos. Although the results of x-rays were negative, his pain rendered him unable to compete in his sport any longer. A computed tomography scan was performed, which showed a bilateral pars fracture

at L5, without spondylolisthesis. A nuclear medicine bone scan revealed negative findings, confirming chronic nonunion. The patient completed a 4-wk course of physical therapy 6 mos before our intervention, without any relief of pain or radiologic evidence of healing. The patient was treated with a bone stimulator for 4 hrs/day and was recommended to wear a warm-and-form-type brace. Isometric core trunk exercises were also initiated. Only after 6 wks of treatment, the subject showed clinical improvement at the follow-up visit. Computed tomography scan performed 12 wks after the initial scan showed complete union of the fracture correlating with clinical improvement. Two years later, the athlete remains completely pain-free, is training regularly, and is able to compete on a national and, possibly, international level.

Ward KA, Roberts SA, et al. (2007). Calcium supplementation and weight bearing physical activity-Do they have a combined effect on the bone density of pre-pubertal children? Bone **41**(4): 496-504.

The adaptation of bone to exercise has been shown to be modified by dietary calcium intake. The aim of this randomised controlled trial was to investigate whether there was a differential response to calcium supplementation in elite gymnasts and school children controls. The primary hypothesis was that gymnasts who took calcium supplements would have greater increases in cortical and trabecular volumetric bone mineral density (vBMD) at the radius and tibia. Secondary outcomes studied were changes in bone geometry at the radius and tibia and lumbar spine and whole body measurements. Children were randomised to 12 months daily supplementation of 500 mg elemental calcium (1250 mg (in the form of calcium carbonate salt)) or placebo. Outcome measures were assessed using peripheral quantitative computed tomography (pQCT) (distal and diaphyseal radius and tibia) and dual energy X-ray absorptiometry (DXA) (lumbar spine and whole body). Eighty-six subjects participated in the trial (44 gymnasts, 42 controls) and 75 subjects completed the trial (39 gymnasts, 36 controls). Data were analysed by analysis of covariance adjusting for baseline value of bone parameters, age, height, gender and puberty, and delay between baseline measurement and start of intervention. The primary analysis was for a calcium-exercise interaction; a pooled calcium effect with no interaction was also tested. Results are presented as ratios (95% confidence intervals). At the distal tibia, trabecular vBMD showed a significant interaction (p=0.04), with controls (1.00: 0.99, 1.09) responding more than gymnasts (0.98: 0.94, 1.02) to supplementation. At the distal radius, change in trabecular vBMD was not significant (p=0.05). There were no differences in change in cortical vBMD at either site between the gymnasts and controls (tibia: p=0.82, radius: p=0.88). For all other secondary outcomes at radius, tibia, spine and whole body no significant interactions were found. In conclusion, there was no beneficial effect of additional calcium in gymnasts who already consume their recommended nutrient intake (888 mg/day; United Kingdom reference nutrient intake for 8- to 11-year-olds is 555-800 mg/day) for calcium. We speculate that gymnasts have already adapted their bones (geometry and vBMD) to the demands imposed upon them by the loading they are subjected to during gymnastics and do not benefit from additional calcium supplementation.

Ward KA, Roberts SA, et al. (2005). Bone geometry and density in the skeleton of pre-pubertal gymnasts and school children. Bone **36**(6): 1012-1018.

We have studied the differences between the peripheral and axial skeleton of pre-pubertal gymnasts and controls. We hypothesised that compared to controls, gymnasts would have larger and stronger radius and tibia diaphyses with greater bone mineral content and larger cross-sectional muscle area. At the distal metaphyseal sites of the radius and tibia, gymnasts would have greater bone cross-sectional area and total and trabecular volumetric bone mineral density (vBMD). Differences between the lumbar spine, total body and body composition in gymnasts versus controls were also studied. Peripheral quantitative computed tomography (pQCT) was used to measure bone geometry, density and muscle of

the peripheral skeleton; dual energy X-ray absorptiometry (DXA) for total body and axial measurements. Eighty-six pre-pubertal children, 44 gymnasts (mean age 9.0 years, range 5.4-11.9 years) and 42 controls (mean age 8.8 years, range 5.6-11.9 years) were studied. Eighty-four children were Caucasian, one child was mixed race, one Chinese. Data were adjusted for age, sex and height. Differences in the effect size between sexes were also tested. At the 50% radius diaphysis gymnasts had larger bones (9.2%, p = 0.0054) with greater cortical area (8.2%, p = 0.022) and stress strain index (surrogate measure of bone strength) than controls (13.6%, p = 0.015). The effect size was different between males and females for cortical thickness (p = 0.03). At the 65% tibia diaphysis, gymnasts had greater cortical area (5.3%, p = 0.057) and thickness (6.2%, p = 0.068) than controls; consequently, bone strength was 5.4% higher (p = 0.14). There were no significant differences in cortical volumetric bone mineral density (vBMD) at the radius or tibia diaphysis between the groups. There was a difference in effect size for tibia muscle cross-sectional area between the sexes (p = 0.035). At the distal radius and tibia total and trabecular vBMD was greater (Total: radius 17%, p < 0.0001, tibia: 5.7%, p = 0.0053; trabecular: radius 21%, p < 0.0001, tibia 4.5%, p = 0.11). Bone size was not different in gymnasts compared to controls Lumbar spine BMC (12.3%, p = 0.0007), areal bone mineral density (aBMD) (9.1%, p = 0.0006) and bone mineral apparent density (BMAD) (7.6%, p = 0.0047) were greater in gymnasts but vertebral size was not significantly different. Likewise, total body BMD (3.5%, p = 0.0057) and BMC (4.78%, p = 0.085) were greater in gymnasts but there were no differences in skeletal size. These data suggest site-specific differences in how the pre-pubertal skeleton develops in response to the repetitive loading it experiences when participating in regular gymnastics. At diaphyseal sites these differences are predominantly in the bone and muscle geometry and not density. Conversely, at trabecular sites, the differences are increased density rather than geometry. In conclusion, the present study has demonstrated skeletal differences between gymnasts and controls. These differences appear to be site and sex specific.

Webb BG, Rettig LA (2008). Gymnastic wrist injuries. Curr Sports Med Rep **7**(5): 289-295.
During gymnastic activities, the wrist is exposed to many different types of stresses, including repetitive motion, high impact loading, axial compression, torsional forces, and distraction in varying degrees of ulnar or radial deviation and hyperextension. Many of these stresses are increased during upper extremity weight-bearing and predispose the wrist to high rates of injury during gymnastics. Distal radius stress injuries are the most common and most documented gymnastic wrist conditions. Other conditions include scaphoid impaction syndrome, dorsal impingement, scaphoid fractures, scaphoid stress reactions/fractures, capitate avascular necrosis, ganglia, carpal instability, triangular fibrocartilage complex tears, ulnar impaction syndrome, and lunotriquetral impingement. It is important to diagnose quickly and accurately the specific injury to initiate expediently the proper treatment and limit the extent of injury. In addition, a gymnast's training regimen should also include elements of injury prevention.